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BY

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FOR

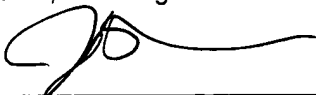
AVIAN LYSOZYME PROMOTER

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**Title of the Invention**

**AVIAN LYSOZYME PROMOTER**

5       The present application claims the benefit of priority from a provisional application filed March 30, 2001 and having U.S. Serial No. 60/280,004.

**Field of the Invention**

10       The present invention relates generally to the identification of an avian lysozyme gene expression control region, specifically from the chicken. More specifically, the invention relates to recombinant nucleic acids and expression vectors, transfected cells and transgenic animals, especially chickens, that comprise the avian lysozyme gene expression control region operably linked to a polypeptide-encoding nucleic acid. The present invention further relates to the  
15       expression of the polypeptide-encoding nucleic acid under the control of the isolated avian lysozyme gene expression control region.

**Background**

20       The field of transgenics was initially developed to understand the action of a single gene in the context of the whole animal and the phenomena of gene activation, expression, and interaction. This technology has also been used to produce models for various diseases in humans and other animals and is amongst the most powerful tools available for the study of genetics, and the

understanding of genetic mechanisms and function. From an economic perspective, the use of transgenic technology to convert animals into "protein factories" for the production of specific proteins or other substances of pharmaceutical interest (Gordon et al., 1987, *Biotechnology* 5: 1183-1187; 5 Wilmot et al., 1990, *Theriogenology* 33: 113-123) offers significant advantages over more conventional methods of protein production by gene expression.

Heterologous nucleic acids have been engineered so that an expressed protein may be joined to a protein or peptide that will allow secretion of the transgenic expression product into milk or urine, from which the protein may then 10 be recovered. These procedures have had limited success and may require lactating animals, with the attendant costs of maintaining individual animals or herds of large species, including cows, sheep, or goats.

Historically, transgenic animals have been produced almost exclusively by microinjection of the fertilized egg. The pronuclei of fertilized eggs are 15 microinjected *in vitro* with foreign, i.e., xenogeneic or allogeneic, heterologous DNA or hybrid DNA molecules. The microinjected fertilized eggs are then transferred to the genital tract of a pseudopregnant female (e.g., Krimpenfort et al., in U.S. Pat. No. 5,175,384).

One system that holds potential is the avian reproductive system. The 20 production of an avian egg begins with formation of a large yolk in the ovary of the hen. The unfertilized oocyte or ovum is positioned on top of the yolk sac.

After ovulation, the ovum passes into the infundibulum of the oviduct where it is fertilized, if sperm are present, and then moves into the magnum of the oviduct which is lined with tubular gland cells. These cells secrete the egg-white proteins, including ovalbumin, lysozyme, ovomucoid, conalbumin and ovomucin,  
5 into the lumen of the magnum where they are deposited onto the avian embryo and yolk.

The hen oviduct offers outstanding potential as a protein bioreactor because of the high levels of protein production, the promise of proper folding and post-translation modification of the target protein, the ease of product  
10 recovery, and the shorter developmental period of chickens compared to other potential animal species. As a result, efforts have been made to create transgenic chickens expressing heterologous proteins in the oviduct by means of microinjection of DNA (PCT Publication WO 97/47739).

The chicken lysozyme gene is highly expressed in the myeloid lineage of  
15 hematopoietic cells, and in the tubular glands of the mature hen oviduct (Hauser et al., 1981, *Hematol. and Blood Transfusion* 26: 175-178; Schutz et al., 1978, Cold Spring Harbor Symp. Quart. Biol. 42: 617-624) and is therefore a suitable candidate for an efficient promoter for heterologous protein production in transgenic animals. The regulatory region of the lysozyme locus extends over at  
20 least 12 kb of DNA 5' upstream of the transcription start site, and comprises a number of elements that have been individually isolated and characterized. The

known elements include three enhancer sequences at about -6.1 kb, -3.9 kb, and -2.7 kb (Grewal et al., 1992, Mol. Cell Biol. 12: 2339-2350; Banifer et al., 1996, J. Mol. Med. 74: 663-671), a hormone responsive element (Hecht et al., 1988, E.M.B.O.J. 7: 2063-2073), a silencer element and a complex proximal  
5 promoter. The constituent elements of the lysozyme gene expression control region are identifiable as DNAase 1 hypersensitive chromatin sites (DHS). They may be differentially exposed to nuclease digestion depending upon the differentiation stage of the cell. For example, in the multipotent progenitor stage of myelomonocytic cell development, or in erythroblasts, the silencer element is a  
10 DHS. At the myeloblast stage, a transcription enhancer located -6.1 kb upstream from the gene transcription start site is a DHS, while at the later monocytic stage another enhancer, at -2.7 kb becomes DNAase sensitive (Huber et al., 1995, DNA and Cell Biol. 14: 397-402).

Scattered throughout the chicken genome, including the chicken lysozyme  
15 locus, are short stretches of nucleic acid that resemble features of Long Terminal Repeats (LTRs) of retrovirus. The function of these elements is unclear but most likely help define the DHS regions of a gene locus (Stein et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80: 6485-6489).

Flanking the lysozyme gene, including the regulatory region, are matrix  
20 attachment regions (5' MAR & 3' MAR), alternatively referred to as "scaffold attachment regions" or SARs. The outer boundaries of the chicken lysozyme

locus have been defined by the MARs (Phi-Van et al., 1988, *E.M.B.O.J.* 7: 655-664; Phi-Van, L. and Stratling, W.H., 1996, *Biochem.* 35: 10735-10742). Deletion of a 1.32 kb or a 1.45 kb halves region, each comprising half of a 5' MAR, reduces positional variation in the level of transgene expression (Phi-Van and Stratling, supra).

The 5' matrix-associated region (5' MAR), located about -11.7 kb upstream of the chicken lysozyme transcription start site, can increase the level of gene expression by limiting the positional effects exerted against a transgene (Phi-Van et al., 1988, *supra*). At least one other MAR is located 3' downstream of the protein encoding region. Although MAR nucleic acid sequences are conserved, little cross-hybridization is seen, indicating significant overall sequence variation. However, MARs of different species can interact with the nucleomatrices of heterologous species, to the extent that the chicken lysozyme MAR can associate with the plant tobacco nucleomatrix as well as that of the chicken oviduct cells (Mlynarona et al., 1994, *Cell* 6: 417-426; von Kries et al., 1990, *Nucleic Acids Res.* 18: 3881-3885).

Gene expression must be considered not only from the perspective of cis-regulatory elements associated with a gene, and their interactions with trans-acting elements, but also with regard to the genetic environment in which they are located. Chromosomal positioning effects (CPEs), therefore, are the variations in levels of transgene expression associated with different locations of

the transgene within the recipient genome. An important factor governing CPE upon the level of transgene expression is the chromatin structure around a transgene, and how it cooperates with the cis-regulatory elements. The cis-elements of the lysozyme locus are confined within a single chromatin domain  
5 (Banifer et al., 1996, supra; Sippel et al., pgs. 133-147 in Eckstein F. & Lilley D.M.J. (eds), "Nucleic Acids and Molecular Biology", Vol. 3, 1989, Springer.

Deletion of a cis-regulatory element from a transgenic lysozyme locus is sufficient to reduce or eliminate positional independence of the level of gene expression (Banifer et al., 1996, supra). There is also evidence indicating that  
10 positional independence conferred on a transgene requires the cotransfer of many kilobases of DNA other than just the protein encoding region and the immediate cis-regulatory elements.

The lysozyme promoter region of chicken is active when transfected into mouse fibroblast cells and linked to a reporter gene such as the bacterial  
15 chloramphenicol acetyltransferase (CAT) gene. The promoter element is also effective when transiently transfected into chicken promacrophage cells. In each case, however, the presence of a 5' MAR element increased positional independency of the level of transcription (Stief et al., 1989, Nature 341: 343-345; Sippel et al., pgs. 257 – 265 in Houdeline L.M. (ed), "Transgenic Animals: Generation and Use").  
20

5 The ability to direct the insertion of a transgene into a site in the genome of an animal where the positional effect is limited offers predictability of results during the development of a desired transgenic animal, and increased yields of the expressed product. Sippel and Steif disclose, in U.S. Patent No. 5,731,178, methods to increase the expression of genes introduced into eukaryotic cells by flanking a transcription unit with scaffold attachment elements, in particular the 5' MAR isolated from the chicken lysozyme gene. The transcription unit disclosed by Sippel and Steif was an artificial construct that combined only the -6.1 kb enhancer element and the proximal promoter element (base position -579 to 10 +15) from the lysozyme gene. Other promoter associated elements were not included. However, although individual cis-regulatory elements have been isolated and sequenced, together with short regions flanking DNA, the entire nucleic acid sequence comprising the functional 5' upstream region of the lysozyme gene has not been determined in its entirety and therefore not 15 employed as a functional promoter to allow expression of a heterologous transgene.

What is still needed, however, is an efficient transcription promoter that will allow expression of a transgene in avian cells that is not subject to positional variation.



What is also needed is a gene expression promoter cassette that will allow expression of a transgene in the oviduct cells of an avian and efficient gene expression regardless of the chromosomal location of the expression system.

5

### **Summary of the Invention**

Briefly described, the present invention relates to a novel isolated avian nucleic acid comprising an avian lysozyme gene expression control region.

The isolated nucleic acid of the present invention is useful for reducing the chromosomal positional effect of a transgene operably linked to the lysozyme gene expression control region and transfected into a recipient cell. By isolating a region of the avian genome extending from 5' upstream of a 5' MAR of the lysozyme locus to the junction between the signal peptide sequence and a polypeptide-encoding region, cis-elements are also included to allow gene expression in a tissue-specific manner. The lysozyme promoter region of the present invention, therefore, will allow expression of an operably linked heterologous nucleic acid insert in a transfected avian cell such as, for example, an oviduct cell.

One aspect of the present invention provides a novel isolated nucleic acid that is located immediately 5' upstream of the native lysozyme-encoding region of the chicken lysozyme gene locus. The novel isolated avian nucleic acid sequence encoding a lysozyme gene expression control region

comprises at least one 5' matrix attachment region, an intrinsically curved DNA region, at least one transcription enhancer element, a negative regulatory element, at least one hormone responsive element, at least one avian CR1 repeat element, and a proximal lysozyme promoter and signal peptide-encoding  
5 region. Interspersed between these constituent elements are stretches of nucleic acid that serve at least to organize the above elements in an ordered array relative to a polypeptide-encoding region.

In one embodiment of the present invention the isolated nucleic acid is isolated from a chicken.

10 The isolated avian lysozyme of the present invention may be operably linked with a selected nucleic acid insert, wherein the nucleic acid insert encodes a polypeptide desired to be expressed in a transfected cell. The nucleic acid insert may be placed in frame with a signal peptide sequence. Translation initiation may start with the signal peptide and continue through the nucleic acid  
15 insert, thereby producing an expressed polypeptide having the desired amino acid sequence.

The recombinant DNA of the present invention may further comprise a polyadenylation signal sequence that will allow the transcript directed by the novel lysozyme gene expression control region to proceed beyond the  
20 nucleic acid insert encoding a polypeptide and allow the transcript to further comprise a 3' untranslated region and a polyadenylated tail. Any functional

polyadenylation signal sequence may be linked to the 3' end of the nucleic acid insert including the SV40 polyadenylation signal sequence, bovine growth hormone adenylation sequence or the like.

5 The sequence of the expressed nucleic acid insert may be optimized for codon usage by a host cell. This may be determined from the codon usage of at least one, and preferably more than one, protein expressed in a chicken cell. For example, the codon usage may be determined from the nucleic acid sequences encoding the proteins ovalbumin, lysozyme, ovomucin and ovotransferrin of chicken.

10 Yet another aspect of the present invention are expression vectors suitable for delivery to a recipient cell for expression of the vector therein. The expression vector of the present invention may comprise an isolated avian lysozyme gene expression control region operably linked to a nucleic acid insert encoding a polypeptide, and optionally a polyadenylation signal sequence. The  
15 expression vector may further comprise a bacterial plasmid sequence, a viral nucleic acid sequence, or fragments or variants thereof that may allow for replication of the vector in a suitable host.

Another aspect of the present invention is a method of expressing a heterologous polypeptide in a eukaryotic cell by transfecting the cell with a  
20 recombinant DNA comprising an avian lysozyme gene expression control region operably linked to a nucleic acid insert encoding a polypeptide and, optionally, a

polyadenylation signal sequence, and culturing the transfected cell in a medium suitable for expression of the heterologous polypeptide under the control of the avian lysozyme gene expression control region.

Also within the scope of the present invention are recombinant  
5 cells; tissues and animals containing non-naturally occurring recombinant nucleic acid molecules according to the present invention and described above. In one embodiment of the present invention, the transformed cell is a chicken oviduct cell and the nucleic acid insert comprises the chicken lysozyme gene expression control region, a nucleic acid insert encoding a human interferon  $\alpha 2b$  and codon  
10 optimized for expression in an avian cell, and an SV40 polyadenylation sequence.

Additional objects and aspects of the present invention will become more apparent upon review of the detailed description set forth below when taken in conjunction with the accompanying figures, which are briefly described as  
15 follows.

### **Brief Description of the Figures**

Fig. 1 illustrates the primers (SEQ ID NO: 1-64) used in the sequencing of  
20 the lysozyme gene expression control region (SEQ ID NO: 67).

Fig. 2 schematically illustrates the approximately 12 kb lysozyme gene expression control region (SEQ ID NO: 67), indicating the relative positions and orientations of the primers (SEQ ID NO: 1-64) used in the sequencing thereof.

5 Fig. 3 illustrates the nucleic acid sequence (SEQ ID NO: 65) comprising the chicken lysozyme gene expression control region (SEQ ID NO: 67), the nucleic acid sequence SEQ ID NO: 66 encoding the chicken expression optimized human interferon  $\alpha$ 2b (IFNMAGMAX) and the SV40 polyadenylation signal sequence (SEQ ID NO: 68).

10

Fig. 4 illustrates the nucleic acid sequence SEQ ID NO: 66 encoding the chicken expression optimized human interferon  $\alpha$ 2b (IFNMAGMAX).

15 Fig. 5 illustrates the nucleic acid sequence SEQ ID NO: 67 encoding the chicken lysozyme gene expression control region.

Fig. 6 illustrates the nucleic acid sequence SEQ ID NO: 68 encoding the SV40 polyadenylation signal sequence.

20 Fig. 7 illustrates the yield of the chicken expression optimized human interferon  $\alpha$ 2b (IFNMAGMAX) in transfected quail oviduct cultured cells.

**Detailed Description of the Preferred Embodiments**

Reference now will be made in detail to the presently preferred  
embodiments of the invention, one or more examples of which are illustrated in  
the accompanying drawings. Each example is provided by way of explanation of  
5 the invention, not limitation of the invention. In fact, it will be apparent to those  
skilled in the art that various modifications, combinations, additions, deletions  
and variations can be made in the present invention without departing from the  
scope or spirit of the invention. For instance, features illustrated or described as  
part of one embodiment can be used in another embodiment to yield a still  
10 further embodiment. It is intended that the present invention covers such  
modifications, combinations, additions, deletions and variations as come within  
the scope of the appended claims and their equivalents.

This description uses gene nomenclature accepted by the Cucurbit  
Genetics Cooperative as it appears in the *Cucurbit Genetics Cooperative Report*  
15 18:85 (1995), herein incorporated by reference in its entirety. Using this gene  
nomenclature, genes are symbolized by italicized Roman letters. If a mutant  
gene is recessive to the normal type, then the symbol and name of the mutant  
gene appear in italicized lower case letters.

For convenience, certain terms employed in the specification, examples,  
20 and appended claims are collected here.

Definitions

The term "animal" is used herein to include all vertebrate animals, including avians and humans. It also includes an individual animal in all stages of development, including embryonic and fetal stages.

5       The term "avian" as used herein refers to any species, subspecies or race of organism of the taxonomic class *ava*, such as, but not limited to, such organisms as chicken, turkey, duck, goose, quail, pheasants, parrots, finches, hawks, crows and ratites including ostrich, emu and cassowary. The term includes the various known strains of *Gallus gallus*, or chickens, (for example, 10   White Leghorn, Brown Leghorn, Barred-Rock, Sussex, New Hampshire, Rhode Island, Ausstralorp, Minorca, Amrox, California Gray, Italian Partidge-colored), as well as strains of turkeys, pheasants, quails, duck, ostriches and other poultry commonly bred in commercial quantities.

      The term "nucleic acid" as used herein refers to any natural and synthetic 15   linear and sequential arrays of nucleotides and nucleosides, for example cDNA, genomic DNA, mRNA, tRNA, oligonucleotides, oligonucleosides and derivatives thereof. For ease of discussion, such nucleic acids may be collectively referred to herein as "constructs," "plasmids," or "vectors." Representative examples of the nucleic acids of the present invention include bacterial plasmid vectors 20   including expression, cloning, cosmid and transformation vectors such as, but not limited to, pBR322, animal viral vectors such as, but not limited to, modified

adenovirus, influenza virus, polio virus, pox virus, retrovirus, and the like, vectors derived from bacteriophage nucleic acid, and synthetic oligonucleotides like chemically synthesized DNA or RNA. The term "nucleic acid" further includes modified or derivatised nucleotides and nucleosides such as, but not limited to, 5 halogenated nucleotides such as, but not only, 5-bromouracil, and derivatised nucleotides such as biotin-labeled nucleotides.

The term "isolated nucleic acid" as used herein refers to a nucleic acid with a structure (a) not identical to that of any naturally occurring nucleic acid or (b) not identical to that of any fragment of a naturally occurring genomic nucleic acid spanning more than three separate genes, and includes DNA, RNA, or derivatives or variants thereof. The term covers, for example, (a) a DNA which has the sequence of part of a naturally occurring genomic molecule but is not flanked by at least one of the coding sequences that flank that part of the molecule in the genome of the species in which it naturally occurs; (b) a nucleic acid incorporated into a vector or into the genomic nucleic acid of a prokaryote or eukaryote in a manner such that the resulting molecule is not identical to any vector or naturally occurring genomic DNA; (c) a separate molecule such as a cDNA, a genomic fragment, a fragment produced by polymerase chain reaction (PCR), ligase chain reaction (LCR) or chemical synthesis, or a restriction fragment; (d) a recombinant nucleotide sequence that is part of a hybrid gene, i.e., a gene encoding a fusion protein, and (e) a recombinant nucleotide



5 resulting nucleic acid molecule still essentially encodes a lysozyme gene  
expression control region or a variant thereof of the present invention.

10 or diseased cells or in the cells from which the sequence was taken. Enriched does not imply that there are no other DNA or RNA sequences present, just that the relative amount of the sequence of interest has been significantly increased. The other DNA may, for example, be derived from a yeast or bacterial genome, or a cloning vector, such as a plasmid or a viral vector. The term "significant" as  
15 used herein is used to indicate that the level of increase is useful to the person making such an increase.

It is advantageous for some purposes that a nucleotide sequence is in purified form. The term “purified” in reference to nucleic acid represents that the sequence has increased purity relative to the natural environment.

20           The terms “polynucleotide,” “oligonucleotide,” and “nucleic acid sequence”  
are used interchangeably herein and include, but are not limited to, coding

sequences (polynucleotide(s) or nucleic acid sequence(s) which are transcribed and translated into polypeptide *in vitro* or *in vivo* when placed under the control of appropriate regulatory or control sequences); control sequences (e.g., translational start and stop codons, promoter sequences, ribosome binding sites, polyadenylation signals, transcription factor binding sites, transcription termination sequences, upstream and downstream regulatory domains, enhancers, silencers, and the like); and regulatory sequences (DNA sequences to which a transcription factor(s) binds and alters the activity of a gene's promoter either positively (induction) or negatively (repression)). No limitation as to length or to synthetic origin are suggested by the terms described herein.

As used herein the terms "polypeptide" and "protein" refer to a polymer of amino acids of three or more amino acids in a serial array, linked through peptide bonds. The term "polypeptide" includes proteins, protein fragments, protein analogues, oligopeptides and the like. The term "polypeptides" contemplates polypeptides as defined above that are encoded by nucleic acids, produced through recombinant technology (isolated from an appropriate source such as a bird), or synthesized. The term "polypeptides" further contemplates polypeptides as defined above that include chemically modified amino acids or amino acids covalently or noncovalently linked to labeling ligands.

The term "fragment" as used herein to refer to a nucleic acid (e.g., cDNA) refers to an isolated portion of the subject nucleic acid constructed artificially

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(e.g., by chemical synthesis) or by cleaving a natural product into multiple pieces, using restriction endonucleases or mechanical shearing, or a portion of a nucleic acid synthesized by PCR, DNA polymerase or any other polymerizing technique well known in the art, or expressed in a host cell by recombinant nucleic acid technology well known to one of skill in the art. The term "fragment" as used herein may also refer to an isolated portion of a polypeptide, wherein the portion of the polypeptide is cleaved from a naturally occurring polypeptide by proteolytic cleavage by at least one protease, or is a portion of the naturally occurring polypeptide synthesized by chemical methods well known to one of skill in the art.

The term "gene" or "genes" as used herein refers to nucleic acid sequences (including both RNA or DNA) that encode genetic information for the synthesis of a whole RNA, a whole protein, or any portion of such whole RNA or whole protein. Genes that are not naturally part of a particular organism's genome are referred to as "foreign genes," "heterologous genes" or "exogenous genes" and genes that are naturally a part of a particular organism's genome are referred to as "endogenous genes". The term "gene product" refers to RNAs or proteins that are encoded by the gene. "Foreign gene products" are RNA or proteins encoded by "foreign genes" and "endogenous gene products" are RNA or proteins encoded by endogenous genes. "Heterologous gene products" are RNAs or proteins encoded by "foreign, heterologous or exogenous genes" and

are, therefore, not naturally expressed in the cell.

The term "expressed" or "expression" as used herein refers to the transcription from a gene to give an RNA nucleic acid molecule at least complementary in part to a region of one of the two nucleic acid strands of the gene. The term "expressed" or "expression" as used herein also refers to the translation from said RNA nucleic acid molecule to give a protein, a polypeptide or a portion thereof.

As used herein, the term "locus" or "loci" refers to the site of a gene on a chromosome. Pairs of genes control hereditary traits, each in the same position on a pair of chromosomes. These gene pairs, or alleles, may both be dominant or both be recessive in expression of that trait. In either case, the individual is said to be homozygous for the trait controlled by that gene pair. If the gene pair (alleles) consists of one dominant and one recessive trait, the individual is heterozygous for the trait controlled by the gene pair. Natural variation in genes or nucleic acid molecules caused by, for example, recombination events or resulting from mutation, gives rise to allelic variants with similar, but not identical, nucleotide sequences. Such allelic variants typically encode proteins with similar activity to that of the protein encoded by the gene to which they are compared, because natural selection typically selects against variations that alter function. Allelic variants can also comprise alterations in the untranslated regions of the gene as, for example, in the 3' or 5' untranslated regions or can involve alternate

splicing of a nascent transcript, resulting in alternative exons being positioned adjacently.

The term "operably linked" refers to an arrangement of elements wherein the components so described are configured so as to perform their usual  
5 function. Control sequences operably linked to a coding sequence are capable of effecting the expression of the coding sequence. The control sequences need not be contiguous with the coding sequence, so long as they function to direct the expression thereof. Thus, for example, intervening untranslated yet transcribed sequences can be present between a promoter sequence and the  
10 coding sequence and the promoter sequence can still be considered "operably linked" to the coding sequence.

The terms "transcription regulatory sequences" and "gene expression control regions" as used herein refer to nucleotide sequences that are associated with a gene nucleic acid sequence and which regulate the transcriptional  
15 expression of the gene. Exemplary transcription regulatory sequences include enhancer elements, hormone response elements, steroid response elements, negative regulatory elements, and the like. The "transcription regulatory sequences" may be isolated and incorporated into a vector nucleic acid to enable regulated transcription in appropriate cells of portions of the vector DNA. The  
20 "transcription regulatory sequence" may precede, but is not limited to, the region of a nucleic acid sequence that is in the region 5' of the end of a protein coding

sequence that may be transcribed into mRNA. Transcriptional regulatory sequences may also be located within a protein coding region, in regions of a gene that are identified as "intron" regions, or may be in regions of nucleic acid sequence that are in the region of nucleic acid.

5           The term "promoter" as used herein refers to the DNA sequence that determines the site of transcription initiation from an RNA polymerase. A "promoter-proximal element" may be a regulatory sequence within about 200 base pairs of the transcription start site.

10           The terms "matrix attachment regions" or "SAR elements" as used herein refer to DNA sequences having an affinity or intrinsic binding ability for the nuclear scaffold or matrix. The MAR elements of the chicken lysozyme locus were described by Phi-Van et al., 1988, *E.M.B.O. J.* 76: 665-664 and Phi-Van, L. and Stratling, W.H., 1996, *Biochem.* 35: 10735-10742, the contents of which are incorporated herein by reference in their entireties.

15           The term "coding region" as used herein refers to a continuous linear arrangement of nucleotides which may be translated into a protein. A full length coding region is translated into a full length protein; that is, a complete protein as would be translated in its natural state absent any post-translational modifications. A full length coding region may also include any leader protein  
20           sequence or any other region of the protein that may be excised naturally from the translated protein.

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The term "complementary" as used herein refers to two nucleic acid molecules that can form specific interactions with one another. In the specific interactions, an adenine base within one strand of a nucleic acid can form two hydrogen bonds with thymine within a second nucleic acid strand when the two  
5 nucleic acid strands are in opposing polarities. Also in the specific interactions, a guanine base within one strand of a nucleic acid can form three hydrogen bonds with cytosine within a second nucleic acid strand when the two nucleic acid strands are in opposing polarities. Complementary nucleic acids as referred to herein, may further comprise modified bases wherein a modified adenine may  
10 form hydrogen bonds with a thymine or modified thymine, and a modified cytosine may form hydrogen bonds with a guanine or a modified guanine.

The term "probe" as used herein, when referring to a nucleic acid, refers to a nucleotide sequence that can be used to hybridize with and thereby identify the presence of a complementary sequence, or a complementary sequence  
15 differing from the probe sequence but not to a degree that prevents hybridization under the hybridization stringency conditions used. The probe may be modified with labels such as, but not only, radioactive groups, biotin, and the like that are well known in the art.

The term "capable of hybridizing under stringent conditions" as used  
20 herein refers to annealing a first nucleic acid to a second nucleic acid under stringent conditions as defined below. Stringent hybridization conditions typically

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permit the hybridization of nucleic acid molecules having at least 70% nucleic acid sequence identity with the nucleic acid molecule being used as a probe in the hybridization reaction. For example, the first nucleic acid may be a test sample or probe, and the second nucleic acid may be the sense or antisense strand of a lysozyme gene expression control region or a fragment thereof. Hybridization of the first and second nucleic acids may be conducted under stringent conditions, e.g., high temperature and/or low salt content that tend to disfavor hybridization of dissimilar nucleotide sequences. Alternatively, hybridization of the first and second nucleic acid may be conducted under reduced stringency conditions, e.g., low temperature and/or high salt content that tend to favor hybridization of dissimilar nucleotide sequences. Low stringency hybridization conditions may be followed by high stringency conditions or intermediate medium stringency conditions to increase the selectivity of the binding of the first and second nucleic acids. The hybridization conditions may further include reagents such as, but not limited to, dimethyl sulfoxide (DMSO) or formamide to disfavor still further the hybridization of dissimilar nucleotide sequences. A suitable hybridization protocol may, for example, involve hybridization in 6X SSC (wherein 1X SSC comprises 0.015 M sodium citrate and 0.15 M sodium chloride), at 65° C in an aqueous solution, followed by washing with 1X SSC at 65° C. Formulae to calculate appropriate hybridization and wash conditions to achieve hybridization permitting 30% or less mismatch between two



nucleic acid molecules are disclosed, for example, in Meinkoth *et al.*, 1984, *Anal. Biochem.* 138: 267-284; the content of which is herein incorporated by reference in its entirety. Protocols for hybridization techniques are well known to those of skill in the art and standard molecular biology manuals may be consulted to  
5 select a suitable hybridization protocol without undue experimentation. See, for example, Sambrook *et al.*, 1989, "Molecular Cloning: A Laboratory Manual", 2nd ed., Cold Spring Harbor Press, the contents of which are herein incorporated by reference in its entirety.

Typically, stringent conditions will be those in which the salt concentration  
10 is less than about 1.5 M Na ion, typically about 0.01 to 1.0 M Na ion concentration (or other salts) from about pH 7.0 to about pH 8.3 and the temperature is at least about 30° C for short probes (e.g., 10 to 50 nucleotides) and at least about 60° C for long probes (e.g., greater than 50 nucleotides). Stringent conditions may also be achieved with the addition of destabilizing  
15 agents such as formamide. Exemplary low stringency conditions include hybridization with a buffer solution of 30 to 35% formamide, 1 M NaCl, 1% SDS (sodium dodecyl sulphate) at 37° Celsius, and a wash in 1x to 2x SSC at 50 to 55° Celsius. Exemplary moderate stringency conditions include hybridization in 40 to 45% formamide, 1 M NaCl, 1% SDS at 37° Celsius, and a wash in 0.5x to  
20 1x SSC at 55 to 60° Celsius. Exemplary high stringency conditions include hybridization in 50% formamide, 1 M NaCl, 1% SDS at 37° Celsius, and a wash

in 0.1x SSC at 60 to 65° Celsius.

The terms "unique nucleic acid region" and "unique protein (polypeptide) region" as used herein refer to sequences present in a nucleic acid or protein (polypeptide) respectively that is not present in any other nucleic acid or protein sequence. The terms "conserved nucleic acid region" as referred to herein is a nucleotide sequence present in two or more nucleic acid sequences, to which a particular nucleic acid sequence can hybridize under low, medium or high stringency conditions. The greater the degree of conservation between the conserved regions of two or more nucleic acid sequences, the higher the hybridization stringency that will allow hybridization between the conserved region and a particular nucleic acid sequence.

The terms "percent sequence identity" or "percent sequence similarity" as used herein refer to the degree of sequence identity between two nucleic acid sequences or two amino acid sequences as determined using the algorithm of Karlin and Attschul, 1990, *Proc. Natl. Acad. Sci.* 87: 2264-2268, modified as in Karlin and Attschul, 1993, *Proc. Natl. Acad. Sci.* 90: 5873-5877. Such an algorithm is incorporated into the NBLAST and XBLAST programs of Attschul et al., 1990, *T. Mol. Biol.* Q15: 403-410. BLAST nucleotide searches are performed with the NBLAST program, score = 100, wordlength = 12, to obtain nucleotide sequences homologous to a nucleic acid molecule of the invention. BLAST protein searches are performed with the XBLAST program, score = 50,

wordlength = 3, to obtain amino acid sequences homologous to a reference polypeptide. To obtain gapped alignments for comparison purposes, Gapped BLAST is utilized as described in Attschul et al., 1997, *Nucl. Acids Res.* 25: 3389-3402. When utilizing BLAST and Gapped BLAST programs, the default  
5 parameters of the respective programs (e.g. XBLAST and NBLAST) are used. See <http://www.ncbi.nlm.nih.gov>. Other algorithms, programs and default settings may also be suitable such as, but not only, the GCG-Sequence Analysis Package of the U.K. Human Genome Mapping Project Resource Centre that includes programs for nucleotide or amino acid sequence comparisons.

10 The term "sense strand" as used herein refers to a single stranded DNA molecule from a genomic DNA that may be transcribed into RNA and translated into the natural polypeptide product of the gene. The term "antisense strand" as used herein refers to the single strand DNA molecule of a genomic DNA that is complementary with the sense strand of the gene.

15 The term "antisense DNA" as used herein refers to a gene sequence DNA that has a nucleotide sequence complementary to the "sense strand" of a gene when read in reverse orientation, i.e., DNA read into RNA in a 3' to 5' direction rather than in the 5' to 3' direction. The term "antisense RNA" is used to mean an RNA nucleotide sequence (for example that encoded by an antisense DNA or  
20 synthesized complementary with the antisense DNA). Antisense RNA is capable of hybridizing under stringent conditions with an antisense DNA. The antisense

RNA of the invention is useful for regulating expression of a "target gene" either at the transcriptional or translational level. For example, transcription of the subject nucleic acids may produce antisense transcripts that are capable of inhibiting transcription by inhibiting initiation of transcription or by competing for limiting transcription factors; the antisense transcripts may inhibit transport of the "target RNA", or, the antisense transcripts may inhibit translation of "target RNA".

The term "nucleic acid vector" as used herein refers to a natural or synthetic single or double stranded plasmid or viral nucleic acid molecule that can be transfected or transformed into cells and replicate independently of, or within, the host cell genome. A circular double stranded plasmid can be linearized by treatment with an appropriate restriction enzyme based on the nucleotide sequence of the plasmid vector. A nucleic acid can be inserted into a vector by cutting the vector with restriction enzymes and ligating the pieces together. The nucleic acid molecule can be RNA or DNA.

The term "expression vector" as used herein refers to a nucleic acid vector that comprises the lysozyme gene expression control region operably linked to a nucleotide sequence coding at least one polypeptide. As used herein, the term "regulatory sequences" includes promoters, enhancers, and other elements that may control gene expression. Standard molecular biology textbooks such as Sambrook et al. eds., 1989, "Molecular Cloning: A Laboratory Manual", 2nd ed., Cold Spring Harbor Press may be consulted to design suitable

expression vectors that may further include an origin of replication and selectable gene markers. It should be recognized, however, that the choice of a suitable expression vector and the combination of functional elements therein depends upon multiple factors including the choice of the host cell to be transformed and/or the type of protein to be expressed.

The terms "transformation" and "transfection" as used herein refer to the process of inserting a nucleic acid into a host. Many techniques are well known to those skilled in the art to facilitate transformation or transfection of a nucleic acid into a prokaryotic or eukaryotic organism. These methods involve a variety of techniques, such as treating the cells with high concentrations of salt such as, but not only a calcium or magnesium salt, an electric field, detergent, or liposome mediated transfection, to render the host cell competent for the uptake of the nucleic acid molecules, and by such methods as sperm-mediated and restriction-mediated integration.

The term "transfecting agent" as used herein refers to a composition of matter added to the genetic material for enhancing the uptake of heterologous DNA segment(s) into a eukaryotic cell, preferably an avian cell, and more preferably a chicken male germ cell. The enhancement is measured relative to the uptake in the absence of the transfecting agent. Examples of transfecting agents include adenovirus-transferrin-polylysine-DNA complexes. These complexes generally augment the uptake of DNA into the cell and reduce its

breakdown during its passage through the cytoplasm to the nucleus of the cell. These complexes can be targeted to the male germ cells using specific ligands that are recognized by receptors on the cell surface of the germ cell, such as the c-kit ligand or modifications thereof.

Other preferred transfecting agents include but are not limited to lipofectin, lipfectamine, DIMRIE C, Supeffect, and Effectin (Qiagen), unifectin, maxifectin, DOTMA, DOGS (Transfectam; dioctadecylamidoglycylspermine), DOPE (1,2-dioleoyl-sn-glycero-3-phosphoethanolamine), DOTAP (1,2-dioleoyl-3-trimethylammonium propane), DDAB (dimethyl dioctadecytammonium bromide), DHDEAB (N,N-di-n-hexadecyl-N,N-dihydroxyethyl ammonium bromide), HDEAB (N-n-hexadecylN,N-dihydroxyethylammonium bromide), polybrene, or poly(ethylenimine) (PEI). These non-viral agents have the advantage that they can facilitate stable integration of xenogeneic DNA sequences into the vertebrate genome, without size restrictions commonly associated with virus-derived transfecting agents.

The term “recombinant cell” refers to a cell that has a new combination of nucleic acid segments that are not covalently linked to each other in nature. A new combination of nucleic acid segments can be introduced into an organism using a wide array of nucleic acid manipulation techniques available to those skilled in the art. A recombinant cell can be a single eukaryotic cell, or a single prokaryotic cell, or a mammalian cell. The recombinant cell may harbor a vector

that is extragenomic. An extragenomic nucleic acid vector does not insert into the cell's genome. A recombinant cell may further harbor a vector or a portion thereof that is intragenomic. The term intragenomic defines a nucleic acid construct incorporated within the recombinant cell's genome.

5           The terms "recombinant nucleic acid" and "recombinant DNA" as used herein refer to combinations of at least two nucleic acid sequences that are not naturally found in a eukaryotic or prokaryotic cell. The nucleic acid sequences may include, but are not limited to, nucleic acid vectors, gene expression regulatory elements, origins of replication, suitable gene sequences that when  
10       expressed confer antibiotic resistance, protein-encoding sequences and the like. The term "recombinant polypeptide" is meant to include a polypeptide produced by recombinant DNA techniques such that it is distinct from a naturally occurring polypeptide either in its location, purity or structure. Generally, such a recombinant polypeptide will be present in a cell in an amount different from that  
15       normally observed in nature.

          Pharmaceutical compositions comprising agents that will modulate the regulation of the expression of a polypeptide-encoding nucleic acid operably linked to a lysozyme gene expression control region can be administered in dosages and by techniques well known to those skilled in the medical or  
20       veterinary arts, taking into consideration such factors as the age, sex, weight, species and condition of the recipient animal, and the route of administration.

The route of administration can be percutaneous, via mucosal administration (e.g., oral, nasal, anal, vaginal) or via a parenteral route (intradermal, intramuscular, subcutaneous, intravenous, or intraperitoneal). Pharmaceutical compositions can be administered alone, or can be co-administered or sequentially administered with other treatments or therapies. Forms of administration may include suspensions, syrups or elixirs, and preparations for parenteral, subcutaneous, intradermal, intramuscular or intravenous administration (e.g., injectable administration) such as sterile suspensions or emulsions. Pharmaceutical compositions may be administered in admixture with a suitable carrier, diluent, or excipient such as sterile water, physiological saline, glucose, or the like. The compositions can contain auxiliary substances such as wetting or emulsifying agents, pH buffering agents, adjuvants, gelling or viscosity enhancing additives, preservatives, flavoring agents, colors, and the like, depending upon the route of administration and the preparation desired.

Standard pharmaceutical texts, such as "Remington's Pharmaceutical Science", 17th edition, 1985 may be consulted to prepare suitable preparations, without undue experimentation. Dosages can generally range from a few hundred milligrams to a few grams.

As used herein, a "transgenic animal" is any animal, such as an avian species, including the chicken, in which one or more of the cells of the avian may contain heterologous nucleic acid introduced by way of human intervention, such



as by transgenic techniques well known in the art. The nucleic acid is introduced into a cell, directly or indirectly by introduction into a precursor of the cell, by way of deliberate genetic manipulation, such as by microinjection or by infection with a recombinant virus. The term genetic manipulation does not include classical cross-breeding, or *in vitro* fertilization, but rather is directed to the introduction of a recombinant DNA molecule. This molecule may be integrated within a chromosome, or it may be extrachromosomally replicating DNA. In the typical transgenic animal, the transgene causes cells to express a recombinant form of the subject polypeptide, e.g., either agonistic or antagonistic forms, or in which the gene has been disrupted. The terms "chimeric animal" or "mosaic animal" are used herein to refer to animals in which the recombinant gene is found, or in which the recombinant is expressed in some but not all cells of the animal. The term "tissue-specific chimeric animal" indicates that the recombinant gene is present and/or expressed in some tissues but not others.

As used herein, the term "transgene" means a nucleic acid sequence (encoding, for example, a human interferon polypeptide) that is partly or entirely heterologous, i.e., foreign, to the transgenic animal or cell into which it is introduced, or, is homologous to an endogenous gene of the transgenic animal or cell into which it is introduced, but which is designed to be inserted, or is inserted, into the animal's genome in such a way as to alter the genome of the cell into which it is inserted (e.g., it is inserted at a location which differs from that

of the natural gene or its insertion results in a knockout). A transgene according to the present invention will include one or more transcriptional regulatory sequences, polyadenylation signal sequences and any other nucleic acid, such as introns, that may be necessary for optimal expression of a selected nucleic acid.

The term "chromosomal positional effect (CPE)" as used herein refers to the variation in the degree of gene transcription as a function of the location of the transcribed locus within the cell genome. Random transgenesis may result in a transgene being inserted at different locations in the genome so that individual cells of a population of transgenic cells may each have at least one transgene, each at a different location and therefore each in a different genetic environment. Each cell, therefore, may express the transgene at a level specific for that particular cell and dependent upon the immediate genetic environment of the transgene. In a transgenic animal, as a consequence, different tissues may exhibit different levels of transgene expression.

Techniques useful for isolating and characterizing the nucleic acids and proteins of the present invention are well known to those of skill in the art and standard molecular biology and biochemical manuals may be consulted to select suitable protocols without undue experimentation. See, for example, Sambrook et al., 1989, "Molecular Cloning: A Laboratory Manual", 2nd ed., Cold Spring Harbor, the content of which is herein incorporated by reference in its entirety.

Abbreviations:

Abbreviations used in the present specification include the following: aa, amino acid(s); bp, base pair(s); cDNA, DNA complementary to RNA; nt, nucleotide(s); SSC, sodium chloride-sodium citrate; DMSO, dimethyl sulfoxide; 5 MAR; matrix attachment region.

Chicken lysozyme gene expression control region nucleic acid sequences: A series of PCR amplifications of template chicken genomic DNA were used to isolate the gene expression control region of the chicken lysozyme locus. Two 10 amplification reactions used the PCR primer sets SEQ ID NOS: 1 and 2 and SEQ ID NOS: 3 and 4. The amplified PCR products were united as a contiguous isolated nucleic acid by a third PCR amplification step with the primers SEQ ID NOS: 1 and 4, as described in Example 1 below.

The isolated PCR-amplified product, comprising about 12kb of the nucleic 15 acid region 5' upstream of the native chicken lysozyme gene locus, was cloned into the plasmid pCMV-LysSPIFNMM. pCMV-LysSPIFNMM comprises a modified nucleic acid insert encoding a human interferon  $\alpha$ 2b sequence and an SV40 polyadenylation signal sequence 3' downstream of the interferon encoding nucleic acid. The sequence SEQ ID NO: 66 of the nucleic acid insert encoding 20 human interferon  $\alpha$ 2b was in accordance with avian cell codon usage, as determined from the nucleotide sequences encoding chicken ovomucin,

ovalbumin, ovotransferrin and lysozyme. The novel chicken lysozyme gene expression control region, interferon-encoding insert and the SV40 polyadenylation signal sequence of the resulting plasmid construct pAVIJCR-A115.93.1.2, constructed as described in Example 1 below, was sequenced  
5 using the artificial oligonucleotide primers SEQ ID NOS: 1-64, as illustrated in Figs. 1 and 2.

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a  
a  
The nucleic acid sequence (SEQ ID NO: 65) of the insert in pAVIJCR-A115.93.1.2 is shown in Fig. 3, with the modified human interferon  $\alpha 2b$  encoding nucleotide sequence SEQ ID NO: 66 and the novel chicken lysozyme gene  
10 expression control region SEQ ID NO: 67, shown in Figs. 4 and 5 respectively. A polyadenylation signal sequence that is suitable for operably linking to the polypeptide-encoding nucleic acid insert is the SV40 signal sequence SEQ ID NO: 68, as shown in Fig. 6.

The inclusion of the novel isolated avian lysozyme gene expression  
15 control region of the present invention upstream of a codon-optimized interferon-encoding sequence in pAVIJCR-A115.93.1.2 allowed expression of the interferon polypeptide in transfected avian cells, as described in Example 5, below. It is contemplated, however, that any nucleic acid sequence encoding a polypeptide may be operably linked to the novel isolated avian lysozyme gene  
20 expression control region so as to be expressed in a transfected avian cell. The plasmid construct pAVIJCR-A115.93.1.2 was transfected into cultured quail

oviduct cells, which were then incubated for about 72 hours. ELISA assays of the cultured media showed that the transfected cells synthesized a polypeptide detectable with anti-human interferon  $\alpha 2b$  antibodies.

The novel isolated chicken lysozyme gene expression control region of the present invention comprises the nucleotide elements that are positioned 5' upstream of the lysozyme-encoding region of the native chicken lysozyme locus and which are necessary for the regulated expression of a downstream polypeptide-encoding nucleic acid. While not wishing to be bound by any one theory, the inclusion of at least one 5' MAR element in the isolated control region may confer positional independence to a transfected gene operably linked to the novel lysozyme gene expression control region.

The isolated lysozyme gene expression control region of the present invention is useful for reducing the chromosomal positional effect of a transgene operably linked to the lysozyme gene expression control region and transfected into a recipient avian cell. By isolating a region of the avian genome extending from a point 5' upstream of a 5' MAR of the lysozyme locus to the junction between the signal peptide sequence and a polypeptide-encoding region, cis-regulatory elements are also included that may allow gene expression in a tissue-specific manner. The lysozyme promoter region of the present invention, therefore, will allow expression of an operably linked heterologous nucleic acid insert in a transfected avian cell such as, for example, an oviduct cell.

a

One aspect of the present invention, therefore, provides a novel isolated nucleic acid that comprises the nucleotide sequence SEQ ID NO: 67, shown in Fig. 5 (~~Genbank Accession No. —~~) and derivatives and variants thereof, that is located immediately 5' upstream of the native lysozyme-encoding region of the chicken lysozyme gene locus.

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In one embodiment of the novel isolated nucleic acid of the present invention, therefore, the avian nucleic acid sequence encoding a lysozyme gene expression control region comprises at least one 5' matrix attachment region, an intrinsically curved DNA region, at least one transcription enhancer element, a negative regulatory element, at least one hormone responsive element, at least one avian CR1 repeat element, and a proximal lysozyme promoter and signal peptide-encoding region. Interspersed between these constituent elements are stretches of nucleic acid that serve at least to organize the above elements in an ordered array relative to a polypeptide-encoding region, such as that encoding for chicken lysozyme. It is contemplated to be within the scope of the present invention that the cis-elements of the lysozyme gene expression control region may be in any linear arrangement that can allow the formation of a transcript comprising the nucleotide sequence or its complement of a nucleic insert operably linked to the lysozyme gene expression control region.

20 In one embodiment of the present invention, the isolated nucleic acid may be isolated from an avian selected from the group consisting of a chicken, a

turkey, a duck, a goose, a quail, a pheasant, a ratite, an ornamental bird or a feral bird.

In another embodiment of the present invention, the isolated nucleic acid is obtained from a chicken. In this embodiment, the isolated nucleic acid has the  
5 sequence of SEQ ID NO: 67, as shown in Fig. 5, or a variant thereof.

Another aspect of the invention provides nucleic acids that can hybridize under high, medium or low stringency conditions to an isolated nucleic acid that encodes a chicken lysozyme gene expression control region having all, a derivative of, or a portion of the nucleic acid sequence SEQ ID NO: 67 shown in  
10 Fig. 5. The nucleotide sequence determined from the isolation of the lysozyme gene expression control region from a chicken (SEQ ID NO: 67) will allow for the generation of probes designed for use in identifying homologs of lysozyme gene expression control regions in other avian species.

Fragments of a nucleic acid encoding a portion of the subject lysozyme  
15 gene expression control region are also within the scope of the invention. As used herein, a fragment of the nucleic acid encoding an active portion of a lysozyme gene expression control region refers to a nucleotide sequence having fewer nucleotides than the nucleotide sequence encoding the entire nucleic acid sequence of the lysozyme gene expression control region.

20 In one embodiment of the present invention, the nucleotide sequence of the isolated DNA molecule of the present invention may be used as a probe in

98: 508), Northern blots (Thomas et al., 1980, *Proc. Natl. Acad. Sci.* 77: 5201-05), and Colony blots (Grunstein et al., 1975, *Proc. Natl. Acad. Sci.* 72: 3961-65)(the contents of which are hereby incorporated by reference in their entireties). Alternatively, the isolated DNA molecules of the present invention can be used in a gene amplification detection procedure such as a polymerase chain reaction (Erich et al., 1991, *Science* 252: 1643-51, the content of which is hereby incorporated by reference in its entirety) or in restriction fragment length polymorphism (RFLP) diagnostic techniques, as described in pgs. 519-522 and 545-547 of Watson et al., 2nd ed., 1992, "Recombinant DNA", Scientific American Books (the contents of which is hereby incorporated by reference in its entirety).

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for binding the labels to the synthetic nucleotides are well known to those of skill in the art. Standard immunology manuals, such as Promega: Protocol and Applications Guide, 2nd Edition, 1991 (Promega Corp., Madison, WI, the content of which is incorporated herein in its entirety), may be consulted to select an appropriate labeling protocol without undue experimentation.

In another embodiment of the present invention, an isolated nucleic acid molecule of the present invention includes a nucleic acid that is at least about 75%, preferably at least about 80%, more preferably at least about 85%, even more preferably at least about 90%, still more preferably at least about 95%, and even more preferably at least about 99%, identical to a chicken-derived lysozyme gene expression control region -encoding nucleic acid molecule as depicted in SEQ ID NO: 67.

In another embodiment of the present invention, an avian lysozyme gene expression control region gene or nucleic acid molecule can be an allelic variant of SEQ ID NO: 67.

The present invention also contemplates the use of antisense nucleic acid molecules that are designed to be complementary to a coding strand of a nucleic acid (i.e., complementary to an mRNA sequence) or, alternatively, complimentary to a 5' or 3' untranslated region of the mRNA. Another use of synthetic nucleotides is as primers (DNA or RNA) for a polymerase chain reaction (PCR), ligase chain reaction (LCR), or the like.

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Synthesized nucleotides can be produced in variable lengths. The number of bases synthesized will depend upon a variety of factors, including the desired use for the probes or primers. Additionally, sense or anti-sense nucleic acids or oligonucleotides can be chemically synthesized using modified nucleotides to increase the biological stability of the molecule or of the binding complex formed between the anti-sense and sense nucleic acids. For example, acridine substituted nucleotides can be synthesized. Protocols for designing isolated nucleotides, nucleotide probes, and/or nucleotide primers are well-known to those of ordinary skill, and can be purchased commercially from a variety of sources (e.g., Sigma Genosys, The Woodlands, TX or The Great American Gene Co., Ramona, CA).

The nucleic acid sequence of a chicken lysozyme gene expression control region nucleic acid molecule (SEQ ID NO: 67) of the present invention allows one skilled in the art to, for example, (a) make copies of those nucleic acid molecules by procedures such as, but not limited to, insertion into a cell for replication by the cell, by chemical synthesis or by procedures such as PCR or LCR, (b) obtain nucleic acid molecules which include at least a portion of such nucleic acid molecules, including full-length genes, full-length coding regions, regulatory control sequences, truncated coding regions and the like, (c) obtain lysozyme gene expression control region nucleic acid homologs in other avian species such as, but not limited to, turkey, duck, goose, quail, pheasant, parrot,

finch, ratites including ostrich, emu and cassowary and, (d) to obtain isolated nucleic acids capable of hybridizing to an avian lysozyme gene expression control region nucleic acid and be used to detect the presence of nucleic acid-related sequences by complementation between the probe and the target nucleic acid.

Such nucleic acid homologs can be obtained in a variety of ways including by screening appropriate expression libraries with antibodies of the present invention, using traditional cloning techniques to screen appropriate libraries, amplifying appropriate libraries or DNA using oligonucleotide primers of the present invention in a polymerase chain reaction or other amplification method, and screening public and/or private databases containing genetic sequences using nucleic acid molecules of the present invention to identify targets. Examples of preferred libraries to screen, or from which to amplify nucleic acid molecules, include but are not limited to mammalian BAC libraries, genomic DNA libraries, and cDNA libraries. Similarly, preferred sequence databases useful for screening to identify sequences in other species homologous to chicken lysozyme gene expression control region include, but are not limited to, GenBank and the mammalian Gene Index database of The Institute of Genomics Research (TIGR).

*Codon-optimized proteins*

Another aspect of the present invention is a recombinant DNA molecule comprising the novel isolated avian lysozyme gene expression control region of the present invention operably linked to a selected polypeptide-encoding nucleic acid insert, and which may express the nucleic acid insert when transfected to a suitable host cell, preferably an avian cell. The nucleic acid insert may be placed in frame with a signal peptide sequence, whereby translation initiation from the transcript may start with the signal peptide and continue through the nucleic acid insert, thereby producing an expressed polypeptide having the desired amino acid sequence.

It is anticipated that the recombinant DNA, therefore, may further comprise a polyadenylation signal sequence that will allow the transcript directed by the novel lysozyme gene expression control region to proceed beyond the nucleic acid insert encoding a polypeptide and allow the transcript to further comprise a 3' untranslated region and a polyadenylated tail. Any functional polyadenylation signal sequence may be linked to the 3' end of the nucleic acid insert including the SV40 polyadenylation signal sequence, bovine growth hormone adenylation sequence or the like, or derivatives thereof.

In one embodiment of the recombinant DNA of the present invention, the polyadenylation signal sequence is derived from the SV40 virus.

In another embodiment of the recombinant DNA of the present invention, the polyadenylation signal has the nucleic acid sequence SEQ ID NO: 68 or a variant thereof, as shown in Fig. 6.

Another aspect of the present invention is to provide nucleic acid sequences of a human interferon  $\alpha 2b$  protein optimized for expression in avian cells, and derivatives and fragments thereof.

In derivatives of the human interferon  $\alpha 2b$  protein of the present invention, for example, it is reasonable to expect that an isolated replacement of a leucine with an isoleucine or valine, an aspartate with a glutamate, a threonine with a serine, or a similar replacement of an amino acid with a structurally related amino acid (i.e. conservative mutations) will not have a major effect on the biological activity of the resulting molecule. Conservative replacements are those that take place within a family of amino acids that are related in their side chains. Genetically encoded amino acids can be divided into four families: (1) acidic = aspartate, glutamate; (2) basic = lysine, arginine, histidine; (3) nonpolar = alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan; and (4) uncharged polar = glycine, asparagine, glutamine, cysteine, serine, threonine, tyrosine. Phenylalanine, tryptophan, and tyrosine are sometimes classified jointly as aromatic amino acids. In similar fashion, the amino acid repertoire can be grouped as (1) acidic = aspartate, glutamate; (2) basic = lysine, arginine histidine, (3) aliphatic = glycine, alanine, valine, leucine,

isoleucine, serine, threonine, with serine and threonine optionally be grouped separately as aliphatic-hydroxyl; (4) aromatic = phenylalanine, tyrosine, tryptophan; (5) amide = asparagine, glutamine; and (6) sulfur-containing = cysteine and methionine. (see, for example, "Biochemistry", 2nd ed, L. Stryer, 5 ed., WH Freeman and Co.,1981). Peptides in which more than one replacement has taken place can readily be tested in the same manner.

One embodiment of the present invention is a recombinant DNA molecule comprising the isolated avian lysozyme gene expression control region of the present invention, operably linked to a nucleic acid insert encoding a 10 polypeptide, and a polyadenylation signal sequence optionally operably linked thereto. It is contemplated that when the recombinant DNA is to be delivered to a recipient cell for expression therein, the sequence of the nucleic acid sequence may be modified so that the codons are optimized for the codon usage of the recipient species. For example, if the recombinant DNA is transfected into a 15 recipient chicken cell, the sequence of the expressed nucleic acid insert is optimized for chicken codon usage. This may be determined from the codon usage of at least one, and preferably more than one, protein expressed in a chicken cell. For example, the codon usage may be determined from the nucleic acid sequences encoding the proteins ovalbumin, lysozyme, ovomucin and 20 ovotransferrin of chicken.

In one embodiment of the recombinant DNA of the present invention, therefore, the nucleic acid insert encodes the human interferon  $\alpha 2b$  polypeptide. Optimization of the sequence for codon usage elevates the level of translation in avian eggs. In this embodiment, the sequence (SEQ ID NO: 66) of the optimized

5 human interferon sequence is shown in Fig. 4.

In yet another embodiment of the present invention, the recombinant DNA comprises the isolated avian lysozyme gene expression control region operably linked to a nucleic acid encoding a human interferon  $\alpha 2b$  and the SV40 polyadenylation sequence, the recombinant DNA having the nucleotide  
10 sequence SEQ ID NO: 65, as shown in Fig. 3, or a variant thereof.

The protein of the present invention may be produced in purified form by any known conventional techniques. For example, chicken cells may be homogenized and centrifuged. The supernatant is then subjected to sequential ammonium sulfate precipitation and heat treatment. The fraction containing the  
15 protein of the present invention is subjected to gel filtration in an appropriately sized dextran or polyacrylamide column to separate the proteins. If necessary, the protein fraction may be further purified by HPLC.

Recombinant nucleic acids, and expression thereof, under the control of an avian  
20 lysozyme promoter.

Another potentially useful application of the novel isolated lysozyme gene

expression control region of the present invention is the possibility of increasing the amount of a heterologous protein present in a bird, (especially the chicken) by gene transfer. In most instances, a heterologous polypeptide-encoding nucleic acid insert transferred into the recipient animal host will operably linked  
5 with the lysozyme gene expression control region, to allow the cell to initiate and continue production of the genetic product protein. A recombinant DNA molecule of the present invention can be transferred into the extra-chromosomal or genomic DNA of the host.

The recombinant DNA nucleic acid molecules of the present invention can  
10 be delivered to cells using conventional recombinant DNA technology. The recombinant DNA molecule may be inserted into a cell to which the recombinant DNA molecule is heterologous (i.e. not normally present). Alternatively, as described more fully below, the recombinant DNA molecule may be introduced into cells which normally contain the recombinant DNA molecule, for example, to  
15 correct a deficiency in the expression of a polypeptide, or where over-expression of the polypeptide is desired.

For expression in heterologous systems, the heterologous DNA molecule is inserted into the expression system or vector of the present invention in proper sense orientation and correct reading frame. The vector contains the necessary  
20 elements for the transcription and translation of the inserted protein-coding sequences, including the novel isolated lysozyme gene expression control



region.

U.S. Patent No. 4,237,224 to Cohen and Boyer, which is hereby incorporated by reference in its entirety, describes the production of expression systems in the form of recombinant plasmids using restriction enzyme cleavage and ligation with DNA ligase. These recombinant plasmids are then introduced to a cell by means of transformation and replicated in cultures, including eukaryotic cells grown in tissue culture.

One aspect of the present invention, therefore, is an expression vector suitable for delivery to a recipient cell for expression of the vector therein. It is contemplated to be within the scope of the present invention for the expression vector to comprise an isolated avian lysozyme gene expression control region operably linked to a nucleic acid insert encoding a polypeptide, and optionally a polyadenylation signal sequence. The expression vector of the present invention may further comprise a bacterial plasmid sequence, a viral nucleic acid sequence, or fragments or variants thereof that may allow for replication of the vector in a suitable host.

The novel isolated avian lysozyme gene expression control region of the present invention (SEQ ID NO: 67) and a polypeptide-encoding nucleic acid sequence operably linked thereto, such as, for example, SEQ ID NO: 66 or a derivative or truncated variant thereof, and optionally a polyadenylation signal sequence such as, for example, SEQ ID NO: 68, may be introduced into viruses

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such as vaccinia virus. Methods for making a viral recombinant vector useful for expressing a protein under the control of the lysozyme promoter are analogous to the methods disclosed in U.S. Patent Nos. 4,603,112; 4,769,330; 5,174,993; 5,505,941; 5,338,683; 5,494,807; 4,722,848; Paoletti, E., 1996, *Proc. Natl. Acad. Sci.*, 93: 11349-11353; Moss, B., 1996, *Proc. Natl. Acad. Sci.* 93: 11341-11348; Roizman, 1996, *Proc. Natl. Acad. Sci.* 93: 11307-11302; Frolov et al., 1996, *Proc. Natl. Acad. Sci.* 93: 11371-11377; Grunhaus et al., 1993, *Seminars in Virology* 3: 237-252 and U.S. Patent Nos. 5,591,639; 5,589,466; and 5,580,859 relating to DNA expression vectors, *inter alia*; the contents of which are incorporated herein by reference in their entirety.

Recombinant viruses can also be generated by transfection of plasmids into cells infected with virus. Suitable vectors include, but are not limited to, viral vectors such as lambda vector system  $\lambda$ gt11,  $\lambda$ gt WES.tB, Charon 4, and plasmid vectors such as pBR322, pBR325, pACYC177, pACYC184, pUC8, pUC9, pUC18, pUC19, pLG339, pR290, pKC37, pKC101, SV 40, pBluescript II SK +/- or KS +/- (see "Stratagene Cloning Systems" Catalog (1993) from Stratagene, La Jolla, Calif., which is hereby incorporated by reference), pQE, pIH821, pGEX, pET series (see Studier, F.W. et al., 1990, *Use of T7 RNA Polymerase to Direct Expression of Cloned Genes* in "Gene Expression Technology," vol. 185, which is hereby incorporated by reference in its entirety) and any derivatives thereof. Recombinant molecules can be introduced into

cells via transformation, particularly transduction, conjugation, mobilization, or electroporation. The DNA sequences are cloned into the vector using standard cloning procedures in the art, as described by Maniatis *et al.*, 1982, *Molecular Cloning: A Laboratory Manual*, Cold Springs Laboratory, Cold Springs Harbor, N.Y., which is hereby incorporated by reference in its entirety.

A variety of host-vector systems may be utilized to express the protein-encoding sequence(s). Primarily, the vector system must be compatible with the host cell used. The use of eukaryotic recipient host cells permits partial or complete post-translational modification such as, but not only, glycosylation and/or the formation of the relevant inter- or intra-chain disulfide bonds. Host-vector systems include but are not limited to the following: bacteria transformed with bacteriophage DNA, plasmid DNA, or cosmid DNA; microorganisms such as yeast containing yeast vectors; vertebrate cell systems infected with virus (e.g., vaccinia virus, adenovirus, etc.); insect cell systems infected with virus (e.g., baculovirus) or avian embryonic cells inoculated with the recombinant nucleic acid. The expression elements of these vectors vary in their strength and specificities. Depending upon the host-vector system utilized, any one of a number of suitable transcription and translation elements can be used.

Once the novel isolated lysozyme gene expression control region of the present invention has been cloned into a vector system, it is ready to be incorporated into a host cell. Such incorporation can be carried out by the

various forms of transformation noted above, depending upon the vector/host cell system. Suitable host cells include, but are not limited to, bacteria, virus, yeast, mammalian cells, and the like. Alternatively, it is contemplated that the incorporation of the DNA of the present invention into a recipient cell may be by  
5 any suitable method such as, but not limited to, viral transfer, electroporation, gene gun insertion, sperm mediated transfer to an ovum, microinjection and the like.

Another aspect of the present invention, therefore, is a method of expressing a heterologous polypeptide in a eukaryotic cell by transfecting the cell  
10 with a recombinant DNA comprising an avian lysozyme gene expression control region operably linked to a nucleic acid insert encoding a polypeptide and, optionally, a polyadenylation signal sequence, and culturing the transfected cell in a medium suitable for expression of the heterologous polypeptide under the control of the avian lysozyme gene expression control region.

15 In one embodiment of the method of the present invention, the recipient eukaryotic cell is derived from an avian. In one embodiment, the avian is a chicken.

Yet another aspect of the present invention is a eukaryotic cell transformed with an expression vector according to the present invention and  
20 described above. In one embodiment of the present invention, the transformed cell is a chicken oviduct cell and the nucleic acid insert comprises the chicken

lysozyme gene expression control region, a nucleic acid insert encoding a human interferon  $\alpha 2b$  and codon optimized for expression in an avian cell, and an SV40 polyadenylation sequence.

It is contemplated that the transfected cell according to the present invention may be transiently transfected, whereby the transfected recombinant DNA or expression vector may not be integrated into the genomic nucleic acid. It is further contemplated that the transfected recombinant DNA or expression vector may be stably integrated into the genomic DNA of the recipient cell, thereby replicating with the cell so that each daughter cell receives a copy of the transfected nucleic acid. It is still further contemplated for the scope of the present invention to include a transgenic animal producing a heterologous protein expressed from a transfected nucleic acid according to the present invention.

In one embodiment of the present invention, the transgenic animal is an avian selected from a turkey, duck, goose, quail, pheasant, ratite, an ornamental bird or a feral bird. In another embodiment, the avian is a chicken and the heterologous protein produced under the transcriptional control of the isolated avian lysozyme gene expression control region according to the present invention is produced in the white of an egg.

Viral vector cell transformation:

An exemplary approach for the *in vivo* introduction of a nucleic acid encoding the subject novel isolated lysozyme gene expression control region into a cell is by use of a viral vector containing nucleic acid, e.g. a cDNA, encoding the gene product. Infection of cells with a viral vector has the advantage that a large proportion of the targeted cells can receive the nucleic acid. Additionally, molecules encoded within the viral vector, e.g., by a cDNA contained in the viral vector, are expressed efficiently in cells that have taken up viral vector nucleic acid.

Retrovirus vectors and adeno-associated virus vectors are generally understood to be the recombinant gene delivery system of choice for the transfer of exogenous genes *in vivo*. These vectors provide efficient delivery of genes into cells, and the transferred nucleic acids are stably integrated into the chromosomal DNA of the host. Recombinant retrovirus can be constructed in the part of the retroviral coding sequence (gag, pol, env) that has been replaced by nucleic acid encoding a lysozyme gene expression control region, thereby rendering the retrovirus replication defective. Protocols for producing recombinant retroviruses and for infecting cells *in vitro* or *in vivo* with such viruses can be found in Ausubel et al, 1989, "Current Protocols in Molecular Biology," Sections 9.10-9.14, Greene Publishing Associates, and other standard laboratory manuals. Examples of suitable retroviruses include pLJ, pZIP, pWE

and pEM, all of which are well known to those skilled in the art. Examples of suitable packaging virus lines for preparing both ecotropic and amphotropic retroviral systems include psiCrip, psiCre, psi2 and psiAm.

Furthermore, it is possible to limit the infection spectrum of retroviruses and consequently of retroviral-based vectors, by modifying the viral packaging proteins on the surface of the viral particle (see, for example PCT publications WO93/25234, WO94/06920, and WO94/11524). For instance, strategies for the modification of the infection spectrum of retroviral vectors include coupling antibodies specific for cell surface antigens to the viral env protein (Roux et al., 1989, *Proc. Natl. Acad. Sci.* 86: 9079-9083; Julan et al., 1992, *J. Gen. Virol.* 73: 3251-3255 and Goud et al., 1983, *Virology* 163: 251-254) or coupling cell surface ligands to the viral env proteins (Neda et al., 1991, *J. Biol. Chem.* 266: 14143-14146)(all of which are incorporated herein by reference in their entireties). Coupling can be in the form of the chemical cross-linking with a protein or other moiety (e.g., lactose to convert the env protein to an asialoglycoprotein), as well as by generating fusion proteins (e.g., single-chain antibody/env fusion proteins). This technique, while useful to limit or otherwise direct the infection to certain tissue types, can also be used to convert an ecotropic vector into an amphotropic vector.

Another viral gene delivery system useful in the present invention utilizes adenovirus-derived vectors. The genome of an adenovirus can be manipulated

such that it encodes a gene product of interest, but is inactivated in terms of its ability to replicate in a normal lytic viral life cycle (see, for example, Berkner et al., 1988, *BioTechniques* 6: 616; Rosenfeld et al., 1991, *Science* 252: 43 1434; and Rosenfeld et al., 1992, *Cell* 68: 143-155, all of which are incorporated herein

5 by reference in their entireties). Suitable adenoviral vectors derived from the adenovirus strain Ad type 5 dl324 or other strains of adenovirus (e.g., Ad2, Ad3, Ad7 etc.) are well known to those skilled in the art. The virus particle is relatively stable and amenable to purification and concentration, and as above, can be modified so as to affect the spectrum of infectivity. Additionally, introduced

10 adenoviral DNA (and foreign DNA contained therein) is not integrated into the genome of a host cell but remains episomal, thereby avoiding potential problems that can occur as a result of insertional mutagenesis in situations where introduced DNA becomes integrated into the host genome (e.g., retroviral DNA). Most replication-defective adenoviral vectors currently in use and therefore

15 favored by the present invention are deleted for all or parts of the viral E1 and E3 genes but retain as much as 80% of the adenoviral genetic material (see, e.g., Jones et al., 1979, *Cell* 16:683; Berkner et al., *supra*; and Graham et al., 1991, pp. 109-127 in "Methods in Molecular Biology," vol. 7, E. J. Murray, ed., Humana, Clifton, N.J., all of which are incorporated herein by reference in their entireties).

20 Expression of an inserted gene such as, for example, encoding the human interferon  $\alpha$ 2b, can be under control of the exogenously added lysozyme gene



expression control region sequences.

Yet another viral vector system useful for delivery of, for example, the subject avian lysozyme gene expression control region operably linked to a nucleic acid encoding a polypeptide, is the adeno-associated virus (AAV).

5 Vectors containing as little as 300 base pairs of AAV can be packaged and can integrate. Space for exogenous DNA is limited to about 4.5 kb. An AAV vector, such as that described in Tratschin et al., 1985, *Mol. Cell. Biol.* 5: 3251-3260, can be used to introduce DNA into cells. A variety of nucleic acids have been introduced into different cell types using AAV vectors (see, for example,  
10 Hermonat et al., 1984, *Proc. Natl. Acad. Sci.* 81: 6466-6470; Tratschin et al., 1985, *Mol. Cell. Biol.* 4: 2072-2081; Wondisford et al., 1988, *Mol. Endocrinol.* 2: 32-39; Tratschin et al., 1984, *J. Virol.* 51: 611-619; and Flotte et al., 1993, *J. Biol. Chem.* 268: 3781-3790, all of which are incorporated herein by reference in their entireties).

15

Non-viral expression vectors:

Most non-viral methods of gene transfer rely on normal mechanisms used by eukaryotic cells for the uptake and intracellular transport of macromolecules. In preferred embodiments, non-viral gene delivery systems of the present  
20 invention rely on endocytic pathways for the uptake of the subject lysozyme gene expression control region and operably linked polypeptide-encoding nucleic acid

by the targeted cell. Exemplary gene delivery systems of this type include liposomal derived systems, poly-lysine conjugates, and artificial viral envelopes.

In a representative embodiment, a nucleic acid comprising the novel isolated lysozyme gene expression control region of the present invention can be  
5 entrapped in liposomes bearing positive charges on their surface (e.g., lipofectins) and (optionally) which are tagged with antibodies against cell surface antigens of the target tissue (Mizuno et al., 1992, *NO Shinkei Geka* 20: 547-551; PCT publication WO91/06309; Japanese patent application 1047381; and European patent publication EP-A-43075, all of which are incorporated herein by  
10 reference in their entirety).

In similar fashion, the gene delivery system comprises an antibody or cell surface ligand that is cross-linked with a gene binding agent such as polylysine (see, for example, PCT publications WO93/04701, WO92/22635, WO92/20316, WO92/19749, and WO92/06180, all of which are incorporated herein by  
15 reference in their entirety). It will also be appreciated that effective delivery of the subject nucleic acid constructs via receptor-mediated endocytosis can be improved using agents which enhance escape of gene from the endosomal structures. For instance, whole adenovirus or fusogenic peptides of the influenza HA gene product can be used as part of the delivery system to induce  
20 efficient disruption of DNA-containing endosomes (Mulligan et al., 1993, *Science* 260-926; Wagner et al., 1992, *Proc. Natl. Acad. Sci.* 89: 7934; and Christiano et

5 viral methods including by gene gun, microinjection, sperm-mediated transfer, or  
the like.

**Transgenic animals:**

Another aspect of the present invention concerns transgenic animals, such as chickens, having a transgene comprising the novel isolated lysozyme gene expression control region of the present invention and which preferably (though optionally) express a heterologous gene in one or more cells in the animal. Suitable methods for the generation of transgenic avians having heterologous DNA incorporated therein are described, for example, in WO 99/19472 to Ivarie et al.; WO 00/11151 to Ivarie et al.; and WO 00/56932 to Harvey et al., all of which are incorporated herein by reference in their entirety.

In various embodiments of the present invention, the expression of the transgene may be restricted to specific subsets of cells, tissues or developmental stages utilizing, for example, *cis*-acting sequences acting on the lysozyme gene expression control region of the present invention and which control gene expression in the desired pattern. Tissue-specific regulatory sequences and

conditional regulatory sequences can be used to control expression of the transgene in certain spatial patterns. Moreover, temporal patterns of expression can be provided by, for example, conditional recombination systems or prokaryotic transcriptional regulatory sequences. The inclusion of a 5' MAR  
5 region in the novel isolated lysozyme gene expression control region of the present invention may allow the heterologous expression unit to escape the chromosomal positional effect (CPE) and therefore be expressed at a more uniform level in transgenic tissues that received the transgene by a route other than through germ line cells.

10 One embodiment of the present invention, therefore, is a transgenic avian having a heterologous polynucleotide sequence comprising a nucleic acid insert encoding the heterologous polypeptide and operably linked to the novel isolated avian lysozyme gene expression control region, the lysozyme gene expression control region comprising at least one 5' matrix attachment region, an intrinsically  
15 curved DNA region, at least one transcription enhancer, a negative regulatory element, at least one hormone responsive element, at least one avian CR1 repeat element, and a proximal lysozyme promoter and signal peptide-encoding region.

In an embodiment of the present invention, the transgenic avian is  
20 selected from a chicken, a turkey, a duck, a goose, a quail, a pheasant, a ratite, an ornamental bird or a feral bird.

In another embodiment of the present invention, the transgenic avian is a chicken.

In still another embodiment of the transgenic avian of the present invention, the transgenic avian includes an avian lysozyme gene expression  
5 control region comprising the nucleic acid sequence in SEQ ID NO: 67, or a degenerate variant thereof.

In yet another embodiment of the transgenic avian of the present invention, the transgenic avian further comprises a polyadenylation signal sequence.

10 In still yet another embodiment of the transgenic avian of the present invention, the polyadenylation signal sequence is derived from the SV40 virus.

In an embodiment of the transgenic avian of the present invention, the polyadenylation signal sequence comprises the nucleic acid sequence in SEQ ID NO: 68, or a degenerate variant thereof.

15 In another embodiment of the transgenic avian of the present invention, the nucleic acid insert encoding a polypeptide has a codon complement optimized for protein expression in an avian.

In yet another embodiment of the transgenic avian of the present invention, the nucleic acid insert encodes an interferon  $\alpha$ 2b polypeptide.

In still another embodiment of the transgenic avian of the present invention, the nucleic acid insert encoding an interferon  $\alpha 2b$  polypeptide comprises the sequence in SEQ ID NO: 66, or a degenerate variant thereof.

In one embodiment of the transgenic avian of the present invention, the transgenic avian comprises the nucleotide sequence in SEQ ID NO: 65, or a degenerate variant thereof.

In another embodiment of the transgenic avian of the present invention, the transgenic avian produces the heterologous polypeptide in the serum or an egg white.

In another embodiment of the transgenic avian of the present invention, the transgenic avian produces the heterologous polypeptide in an egg white.

The present invention is further illustrated by the following examples, which are provided by way of illustration and should not be construed as limiting.

The contents of all references, published patents and patents cited throughout the present application are hereby incorporated by reference in their entireties.

#### **Example 1: Construction of lysozyme promoter plasmids**

The chicken lysozyme gene expression control region was isolated by PCR amplification. Ligation and reamplification of the fragments thereby obtained yielded a contiguous nucleic acid construct comprising the chicken

lysozyme gene expression control region operably linked to a nucleic acid sequence optimized for codon usage in the chicken (SEQ ID NO: 66) and encoding a human interferon  $\alpha$ 2b polypeptide optimized for expression in an avian cell.

5 White Leghorn Chicken (*Gallus gallus*) genomic DNA was PCR amplified using the primers 5pLMAR2 (SEQ ID NO: 1) (see Fig. 1) and LE-6.1kbrev1 (SEQ ID NO: 2) in a first reaction, and Lys-6.1 (SEQ ID NO: 3) and LysE1rev (SEQ ID NO: 4) as primers in a second reaction. PCR cycling steps were: denaturation at 94°C for 1 minute; annealing at 60°C for 1 minute; extension at 72°C for 6  
10 minutes, for 30 cycles using TAQ PLUS PRECISION™ DNA polymerase (Stratagene, LaJolla, CA). The PCR products from these two reactions were gel purified, and then united in a third PCR reaction using only 5pLMAR2 (SEQ ID NO: 1) and LysE1rev (SEQ ID NO: 4) as primers and a 10-minute extension period. The resulting DNA product was phosphorylated, gel-purified, and cloned  
15 into the *EcoR* V restriction site of the vector pBluescript KS, resulting in the plasmid p12.0-lys.

p12.0-lys was used as a template in a PCR reaction with primers 5pLMAR2 (SEQ ID NO: 1) and LYSBSU (SEQ ID NO: 5) and a 10 minute extension time. The resulting DNA was phosphorylated, gel-purified, and cloned  
20 into the *EcoR* V restriction site of pBluescript KS, forming plasmid p12.0lys-B.

p12.0lys-B was restriction digested with *Not* I and *Bsu*36 I, gel-purified, and cloned into *Not* I and *Bsu*36 I digested pCMV-LysSPIFNMM, resulting in p12.0-lys-LSPIFNMM. p12.0-lys-LSPIFNMM was digested with *Sal* I and the SalItoNotI primer (SEQ ID NO: 6) was annealed to the digested plasmid, followed by *Not* I digestion. The resulting 12.5 kb *Not* I fragment, comprising the lysozyme promoter region linked to IFNMAGMAX-encoding region and an SV40 polyadenylation signal sequence, was gel-purified and ligated to *Not* I cleaved and dephosphorylated pBluescript KS, thereby forming the plasmid pAVIJCR-A115.93.1.2. The lysozyme promoter/IFN construct contained in the plasmid pAVIJCR-A115.93.1.2 was sequenced as described in Example 2.

### **Example 2: Sequencing Reactions**

Plasmid DNA (pAVIJCR-A115.93.1.2) produced as described in Example 1 was purified with QIAGEN™ columns (Qiagen, Valencia, CA). Sequencing reactions were performed according to the Applied Biosystems (Foster City, CA) protocol for BIGDYE™ Terminators, version 2.0, using an ABI 373 Stretch sequencer. The sequencing primers used are listed in Fig. 1, and a schematic diagram illustrating the sequencing reactions using the different primers is shown in Fig. 2. Sequence data was analyzed with SEQUENCHER™ software, version 4.0 (Gene Codes Corp., Ann Arbor, MI).



**Example 3: Complete lysozyme promoter and IFNMAGMAX sequences**

The complete nucleotide sequence (SEQ ID NO: 65), shown in Fig. 3, of the 12.5 kb chicken lysozyme promoter region/IFNMAGMAX construct spans the 5' matrix attachment region (5' MAR), through the lysozyme signal peptide, to the sequence encoding the gene IFNMAGMAX and the subsequent polyadenylation signal sequence. The IFNMAGMAX nucleic acid sequence (SEQ ID NO: 66), shown in Fig. 4, encoded human interferon  $\alpha$ 2b (IFN) that had been synthesized based on a codon usage table compiled from the four most abundantly expressed hen egg white proteins ovalbumen, ovotransferrin, ovomucoid and lysozyme. The expressed IFN  $\alpha$ 2b sequence within plasmid pAVIJCR-A115.93.1.2 functioned as a reporter gene for lysozyme promoter activity. This plasmid construct may also be used for production of interferon  $\alpha$ 2b in the egg white of transgenic chickens. The isolated sequence of the 11.94 kb chicken lysozyme promoter region (SEQ ID NO: 67) alone is shown in Fig. 5. The sequence of the SV40 polyadenylation signal sequence (SEQ ID NO: 68) is shown in Fig. 6.

**Example 4: Basic Local Alignment Search Tool (BLAST) Analysis of the**

**Complete Lysozyme Promoter Sequence (SEQ ID NO: 65)**

The complete 12.5 kb lysozyme promoter/IFNMAGMAX sequence (SEQ ID NO: 65) was submitted to the National Center for Biotechnology Information

for BLAST alignments with database sequences. Percent identities between the lysozyme promoter sequence (SEQ ID NO: 67, included within SEQ ID NO: 65) and corresponding known lysozyme promoter features are shown in Table II below:

5 Table II. BLAST Results of the Complete 12.0 kb Lysozyme Promoter Sequence

| Description of DNA element                    | Coordinates in this sequence | GenBank accession number    | % identity |
|---|------------------------------|-----------------------------|------------|
| 5' matrix attachment region                   | 1-237, 261-1564              | AJ277960                    | 96         |
| 5' matrix attachment region                   | 1-237, 261-1564              | X98408                      | 96         |
| 5' matrix attachment region                   | 1564-1912<br>1930-2015       | X84223                      | 99         |
| Intrinsically curved DNA                      | 2011-2671                    | X52989                      | 98         |
| Transcription enhancer (-6.1 kb)              | 5848-5934                    | <u>Grewal et al.</u> , 1992 | 100        |
| Transcription enhancer (E-2.7 kb)             | 9160-9329                    | X05461                      | 98         |
| Negative regulatory element                   | 9325-9626                    | X05463                      | 98         |
| Hormone response element                      | 9621-9666<br>9680-10060      | X12509                      | 99         |
| CR1 chicken repeat element                    | 10576-10821,<br>10926-11193  | U88211, K02907              | 87         |
| Transcription enhancer (E-0.2 kb)             | 11655-11797                  | X05462                      | 100        |
| Proximal promoter and lysozyme signal peptide | 11563-11877                  | M12532                      | 100        |
| Proximal promoter and lysozyme signal peptide | 11424-11938                  | J00886                      | 99         |

Features that have been previously identified as individual elements isolated from other component elements of the lysozyme promoter region include the 5' MAR, three transcription enhancers, a hormone-responsive

element, and a chicken repeat 1 (CR1) element. The IFNMAGMAX sequence (SEQ ID NO: 66) extended from nucleotide positions 11946 to 12443 of SEQ ID NO: 65, shown in Fig. 3.

5      **Example 5: Expression in Transfected Cultured Avian Oviduct Cells of Human Interferon  $\alpha$ 2b Regulated by the 12kb Lysozyme Promoter**

092549 030301  
The oviduct was removed from a Japanese quail (*Coturnix coturnix japonica*) and the magnum portion minced and enzymatically dissociated with 0.8 mg/ml collagenase (Sigma Chemical Co., St. Louis, MO) and 1.0 mg/ml dispase (Roche Molecular Biochemicals, Indianapolis, IN) by shaking and  
10      titrating for 30 minutes at 37°C. The cell suspension was then filtered through sterile surgical gauze, washed three times with F-12 medium (Life Technologies, Grand Island, NY) by centrifugation at 200 x g, and resuspended in OPTIMEM™ (Life Technologies) such that the OD<sub>600</sub> was approximately 2. Cell suspension  
15      (300  $\mu$ l) was plated per well of a 24-well dish. For each transfection, 2.5  $\mu$ l of DMRIE-C liposomes (Life Technologies) and 1  $\mu$ g of DNA were preincubated for 15 minutes at room temperature in 100  $\mu$ l of OPTIMEM™, and then added to the oviduct cells. Cells with DNA/liposomes were incubated for 5 hours at 37°C in 5% CO<sub>2</sub>. Next, 0.75 ml of DMEM (Life Technologies) supplemented with 15%  
20      fetal bovine serum (FBS) (Atlanta Biologicals, Atlanta, GA), 2X

penicillin/streptomycin (Life Technologies),  $10^{-6}$  M insulin (Sigma),  $10^{-8}$  M  $\alpha$ -estradiol (Sigma), and  $10^{-7}$  M corticosterone (Sigma) was added to each well, and incubation was continued for 72 hours. Medium was then harvested and centrifuged at  $110 \times g$  for 5 minutes. The supernatant was analyzed by ELISA

5 for human interferon  $\alpha 2b$  content.

The human interferon  $\alpha 2b$  contents of medium derived from cultured oviduct cells transfected with either the -12.0 kb IFN plasmid (pAVIJCR-A115.93.1.2) or the negative control plasmid pCMV-EGFP as shown in Fig. 7. Bars to the right of the figure represent the standards for the IFN ELISA.

10